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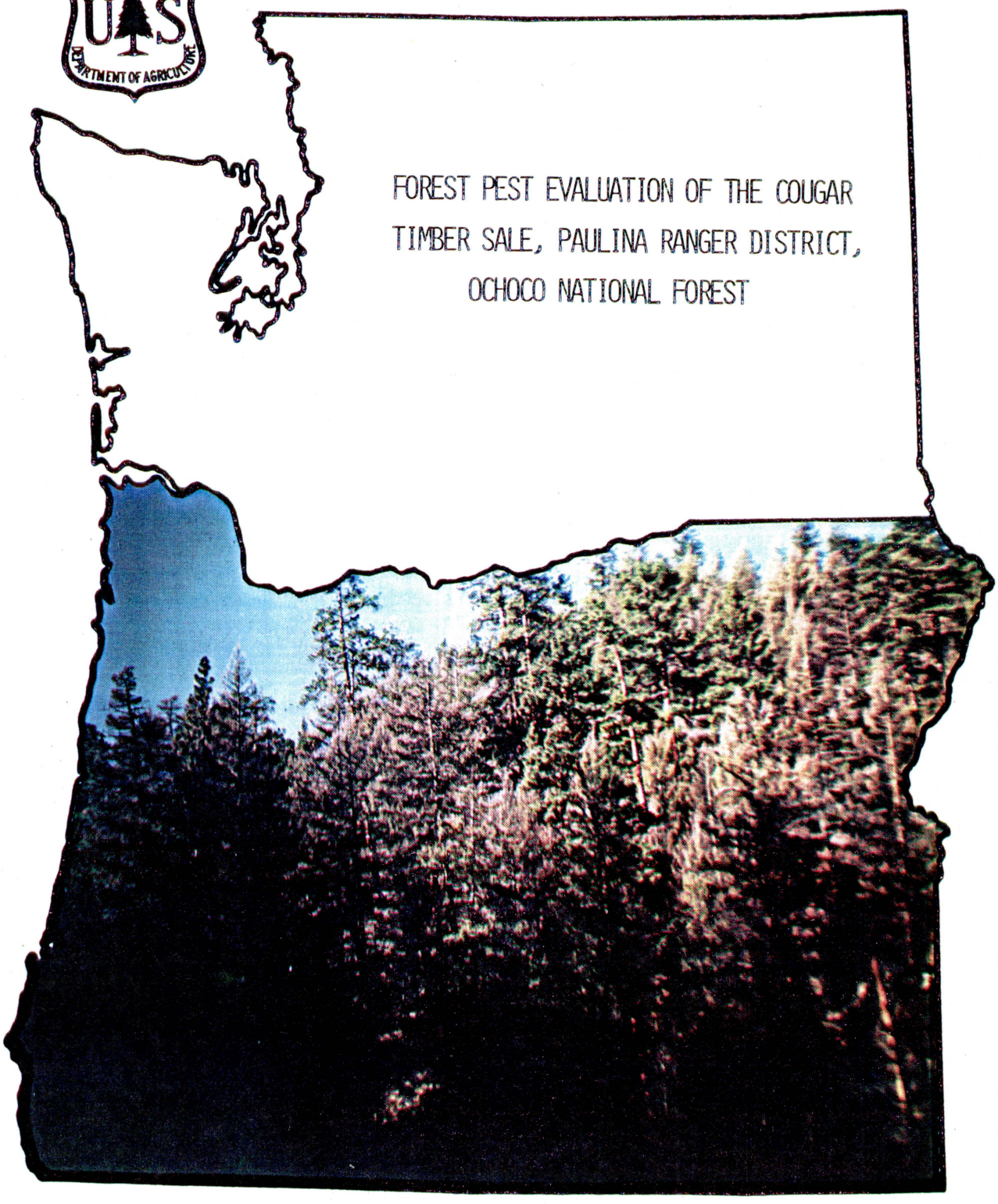
Forest Pest Management
Pacific Northwest Region



FOREST PEST EVALUATION OF THE COUGAR TIMBER SALE, PAULINA RANGER DISTRICT, OCHOCO NATIONAL FOREST

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Introduction

During the week of October 6 to 9, 1986, members of the Forest Pest Management Staff conducted an evaluation on a portion of the Cougar Timber Sale. They were accompanied by Don Wood, Silviculturist, Ochoco National Forest. The Cougar Timber Sale (T. 16 S., R. 26 E., secs. 13, 14, 23, and 24) had been marked and sold in 1979. The original prescription for the unit involved an overstory removal with retention and subsequent management of the advanced regeneration in the understory. The Sale was not harvested and, following buy-back legislation, was returned to the USDA Forest Service. While considering resale, the validity of the original prescription was questioned by the District and Forest Silviculture staffs in light of the apparent high levels of Douglas-fir dwarf mistletoe (Arceuthobium douglasii) infection and western spruce budworm (Choristoneura occidentalis) defoliation in the understory. Purposes of the present FPM evaluation were to determine distribution and severity of insect and disease damage in the unit and provide pest management recommendations.

Methods

The stand was surveyed systematically using a variable plot cruise technique. A Spiegel Relaskop was employed to define plots (BAF 40), and plots were located on a 5 x 10 chain grid across the unit (Fig. 1). A breakpoint DBH of 3 inches was used, and the fixed radius plot size represented 1/300th of an acre.

Region 6 Standard Examination procedures were used to record data on the R6 Stand Exam Plot Data form, modified for western spruce budworm impact evaluation (FPM WSBW Version). Hostetler, Gregg, and Colbert (1986) modified the form in Fields 40 to 53 to include the following information: Field 40 - Tree Number; Field 41 - Species; Field 42 - Class; Field 43 - DBH; Field 44 - Height; Field 45 - Dead Top; Field 46 - Bare Top; Field 47 - Crown Base; Field 48 - Missing Foliage; Field 49 - Current Defoliation; Field 50 - Crown Class; and Fields 51 to 53 - Damage/Severity.

The specific procedures for measurement of Fields 45 to 49 are covered by Hostetler et al. (1986). For the purpose of this evaluation, these fields are estimated or defined as follows:

Dead Top	That dead proportion of the total tree height measured from the top down to the first live current season's bud or shoot, in 1 percent increments.
Bare Top	That bare proportion of the total tree height measured from the top down to the level where the first old foliage is showing, in 1 percent increments.

Crown Base	That proportion of total tree height, measured to the nearest 1 percent increment, down to the level base of the crown. Uneven crown growth and/or uneven crown distribution was visually adjusted to achieve a balanced crown, as per instructions in the Stand Exam Program Field Procedures Guide (p. 43).
Missing Foliage	An ocular estimate of the percentage of the total complement of foliage that is missing due to budworm feeding, recorded to the nearest 10 percent class.
Current Defoliation	An ocular estimate of the percentage of defoliation of current year's foliage, recorded to the nearest 10 percent class.

Data on dwarf mistletoe infection and severity, as well as occurrence and severity of other diseases, were recorded in the standard fashion in Fields 51 to 53. The Hawksworth 6-class system was used to rate mistletoe-infected trees (Hawksworth, 1977).

Western spruce budworm, Douglas-fir dwarf mistletoe, and root disease stand exam data were subjected to analysis using a program for variable radius plots (VPLOT), to develop stand tables incorporating the pest data.

Douglas-fir dwarf mistletoe and root disease data are presented in the tables on the basis of occurrence and host tree status; e.g., alive or dead. However, spruce budworm defoliation is reported in five categories: very light, light, moderate, heavy, and very heavy (adapted from Carolin and Coulter, 1972).

Results

The overstory on the surveyed portion on the Cougar Timber Sale is lightly stocked and composed mostly of old-growth ponderosa pine, with a few large Douglas-fir intermixed and western juniper on the drier ridges. The understory is heavily stocked and comprised primarily of Douglas-fir. Approximately 54 percent of the total basal area per acre and 88 percent of the total trees per acre are poletimber-size or smaller Douglas-fir (Table 1). The quadratic mean DBH of the Douglas-fir component of the Cougar unit is 13.5 inches.

A few ponderosa pine were infested by western pine beetle, Dendroctonus brevicomis. Most were older attacks, predating the current budworm infestation. A minor amount of damage to current foliage, caused by the pine needle sheathminer (Zelleria haimbachi) was also noted. No significant tree-killing diseases were observed on pine, though some Elytroderma needle cast, caused by Elytroderma deformans, was observed causing crown deformation.

Douglas-fir in both the overstory and the understory were found to be heavily infected by Douglas-fir dwarf mistletoe and suffering considerable defoliation by western spruce budworm.

Douglas-fir Dwarf Mistletoe

Douglas-fir dwarf mistletoe was distributed throughout the area surveyed and was severe in most parts. Trees of all sizes were affected (Table 2). Overall, 40 percent of all Douglas-fir (containing 48 percent of the Douglas-fir basal area) was infected by dwarf mistletoe, and actual infection levels are undoubtedly higher since overtopped understory trees often have undetectable latent infections. Virtually all trees over 16 inches DBH exhibited infections. Average dwarf mistletoe rating for all infected trees was 2.9.

Of all mistletoe-infected trees, 31 percent (containing 25 percent of the basal area) were dead. Occurrence of dwarf mistletoe-caused mortality was distributed throughout nearly all size classes (Table 2).

Western Spruce Budworm

Western spruce budworm was first detected on the Cougar unit during the 1984 Cooperative Aerial Insect Detection Survey. Since then, Douglas-fir has experienced considerable defoliation and damage. In this evaluation, damage was divided into the following components: dead top, bare top, missing foliage, and current defoliation.

Out of the total Douglas-fir, 19 percent of the trees per acre, representing 22 percent of the basal area per acre, experienced some degree of top-kill, most of which was 5 percent or less of total tree height (Table 3). Trees in the 1 to 5 percent top-kill class are primarily poletimber-sized with a quadratic mean DBH of 9.5 inches. Trees in the more severe top-kill classes were generally larger but were few in number. For example, quadratic mean DBH for top-kill classes 6 to 10, 11 to 20, and 21 percent and over, are 25.4, 8.0, and 15.5, respectively.

Bare tops (defoliated but not necessarily dead) resulting from feeding by western spruce budworm were generally concentrated in the 14 inch and smaller diameter classes. Considering all diameter classes, bare tops occurred in 85 percent of the Douglas-fir trees per acre, involving 89 percent of the live Douglas-fir basal area per acre (Table 4). Results indicate that roughly equal proportions of trees fell into all bare top categories with the exception of the 1 to 5 percent bare top category.

Budworm defoliation occurred in nearly every diameter class of Douglas-fir on the Cougar unit (Table 5). It is also clear from Table 5, that the heaviest defoliation occurred in the smallest diameter trees. The average diameter of very lightly defoliated trees was 16.0 inches, as contrasted with the average diameter of 6.8 inches for the very heavily defoliated trees.

Most of the current year's defoliation fell into the heavy and very heavy categories (Table 5). Current defoliation was more severe than past years. As a class, the very heavy defoliation category represents 86 percent of the total Douglas-fir per acre.

Discussion

Pest problems associated with the primary ponderosa pine overstory in the Cougar Timber Sale are inconsequential and, therefore, will not be further addressed. The Douglas-fir component, on the other hand, is experiencing significant damage due to mistletoe, as well as defoliation and some top-killing by western spruce budworm. Following are more detailed discussions of the two major pests damaging the Douglas-fir on the surveyed portion of the Cougar unit.

Douglas-fir Dwarf Mistletoe

The dwarf mistletoes are parasitic higher plants that are quite host-specific. In the survey area, Douglas-fir dwarf mistletoe infects only Douglas-fir. Spread is by forcibly discharged seeds that are shot out from mature female plants and fall into the crowns of other trees below the host tree. Thus, conditions in multistoried stands, such as that on the Cougar Timber Sale, are particularly favorable for dwarf mistletoe spread and buildup. On the average, Douglas-fir dwarf mistletoe seeds are shot out a distance of 10 feet. Once a mistletoe seed lands on susceptible host foliage, its sticky coating allows it to slide down to the twig and adhere at the base of a needle. The seed then germinates and produces an infection peg that grows into the host tissue. With time, the mistletoe plant develops both aerial shoots and a sinker system (comparable to a root system) incorporated within the host. The dwarf mistletoe obtains food and water from the host and, at the same time, induces abnormal growth in the tree, resulting in swellings and witches'-brooms (Fig. 2).

Douglas-fir dwarf mistletoe is considered to be the most damaging disease of East side Douglas-fir. Obvious kinds of losses caused by the disease include direct tree mortality and wood quality losses due to stem distortion, top-killing, and formation of large knots associated with witches'-brooms. Mistletoe-caused tree mortality is currently occurring at very high levels in the Cougar Timber Sale. In addition to mortality and wood quality losses, studies indicate that Douglas-fir dwarf mistletoe also causes significant amounts of growth loss in infected stands (Weir, 1918; Pierce, 1960; Haglund and Dooling, 1972). Growth loss is greatest in stands where a high percentage of trees are infected and large portions of tree crowns are occupied by witches'-brooms as is the case in much of the stand on the Cougar unit (Fig. 3). Infection levels being equal, growth loss is greater in intermediate-aged than young or old stands and in moderately-stocked rather than sparsely- or very heavily-stocked stands. Given the characteristics of the Douglas-fir understory on the Cougar Timber Sale and the existing high level of dwarf mistletoe infection, we estimate, using Pierce's (1960) guidelines, that, if

the understory was retained as originally prescribed, subsequent growth would be 50 to 70 percent less than in a similar uninfected stand. Long-term management of Douglas-fir with even moderate levels of dwarf mistletoe infection is ill-advised. Consequently, management of understory Douglas-fir on the Cougar Timber Sale, as originally prescribed, is inappropriate, based on dwarf mistletoe considerations alone. The added impacts of spruce budworm make the prescription even less desirable.

The fact that Douglas-fir dwarf mistletoe is an obligate parasite, and specific to Douglas-fir, can be used in formulating control options for the pathogen. Control can be attained by converting infected stands to nonsusceptible tree species or by eliminating dwarf mistletoe along with its hosts in a regeneration harvest (clearcut, shelterwood, or seed tree cut). Following a clearcut, Douglas-fir can be reestablished on a formerly diseased site without danger of reinfection as long as the new stand is not contiguous to other mistletoe-infected stands. Following a shelterwood or seed tree cut, Douglas-fir regeneration can be managed if the infected overwood is removed before new trees are 10 years old or 3 feet tall.

Western Spruce Budworm

The western spruce budworm is one of the most destructive defoliators of coniferous forests in western North America (Fellin and Dewey, 1982). It is present nearly everywhere its host type occurs in the West. Budworm outbreaks in the Pacific Northwest Region generally are confined to East side conifer stands, but have occurred with rare frequency west of the Cascade Range, as well. Douglas-fir and true firs are considered the principal hosts for western spruce budworm (Freeman, 1967).

The western spruce budworm completes one generation a year throughout most of its range. In Oregon and Washington, adults fly in late July or early August, mate, and lay eggs on the underside of needles. After eggs hatch, the larvae seek overwintering sites on limbs, boles, under bark scales, or in other protected places. Here they overwinter within silken sheaths (hibernacula). In early May, larvae becomes active and bore into old needles and developing buds to feed. Larvae leave the year-old needles and feed on new foliage when it flushes, webbing together needles to form a shelter as it feeds. By early July, the damaged needles turn reddish brown and become visible from a distance. Larvae usually complete development in July, transform into pupae, and emerge as adult about 10 days later. Staminate flowers and conelets are favored, and occasionally terminal and lateral shoots are damaged by budworm on some hosts. Budworm outbreaks (typically lasting from 6 to 10 years) may result in growth loss, top-kill, deformity, reduced seed production, and mortality (Van Sickle, 1985).

Although little or no budworm-caused tree mortality has occurred yet on the Cougar unit, the potential for the insect to contribute to mortality exists. This may be particularly true of trees severely weakened by dwarf mistletoe. Currently, almost 30 percent of the Douglas-fir on the unit is being affected

by both pests. Some Canadian studies have shown that top-kill and mortality generally develop late in the outbreak and involve small, suppressed trees (Alfaro et al., 1982; MacLean, 1985). Our experience in this Region, however, indicates that in some situations, older trees in other crown classes sustain top-kill and mortality, as well. Budworm-caused top-kill or mortality in Douglas-fir can usually be delayed several years, through the production of stress-stimulated adventitious buds and epicormic branches.

The relatively high percentage of Douglas-fir with top-kill (19.1%) in the Cougar unit is a matter for concern. This level of damage is especially bothersome in view of the fact that we believe the budworm outbreak is only in its third year. Dwarf mistletoe may have contributed to some of the damage, especially in larger trees. Since the survey was done in October, it was difficult to tell if some tops were killed or defoliated, and we may have overestimated the amount of top-kill. Nevertheless, the magnitude of damage seems unusually high.

The majority of top-kill on the Cougar Timber Sale was confined to 5 percent or less of the total tree height. It is possible that actual top-kill may extend down beyond the point at which it was measured during our evaluation. In a study of severely defoliated Douglas-fir in British Columbia, Van Sickle (1983) found, for example, that 10 years of height growth loss resulted after only 5 years of budworm feeding. Although it is too early to say how much additional height growth loss may occur beyond that already measured on the Cougar unit, we do believe that it could be significant.

Recovery from top-kill does occur but may result in stem deformaties with some associated volume loss. In instances where only the last year or two of terminal leader are killed, a lateral branch soon achieves dominance and becomes the new functioning leader (Van Sickle, 1985). The dead top, however, could possibly serve as an infection court for decay fungi and result in additional volume losses. Ferrell and Scharpf (1982) found, for example, that decay accounted for the majority of stem volume losses in grand firs that had been top-killed over the course of three separate western spruce budworm outbreaks in Idaho. Since decay--should it occur--would not be evident in top-killed trees on the Cougar unit for a number of years, we can only suggest it as a potential source of stem volume loss.

The significance of an analysis of bare tops lies in the probability that, with continuing defoliation, more trees may eventually move from the "bare top" category into the "dead top" category. An average of 19.1 percent of the Douglas-fir trees per acre on the Cougar Timber Sale have some amount of dead top associated with them; whereas, 85 percent of the Douglas-fir trees per acre exhibit some measure of bare top. Bare tops were especially noticeable in the larger trees.

Missing foliage is used in this evaluation to assess the loss of photosynthetic surface area over the course of an outbreak, due to budworm. In some areas of the Cougar Timber Sale, heavy budworm feeding has resulted in 100 percent defoliation of some trees (Fig. 4). We have long recognized the relationship between defoliation and radial growth loss, but detailed studies to quantify incremental growth loss, or attempts to correlate them with severity and duration of defoliation only now are being conducted. In one such study in British Columbia, it was shown that volume losses ranged from 8.7 percent of the potential volume in trees less than 50 percent defoliated to 17.8 percent in the 90- to 100-percent class (Van Sickle, 1985). In this same study, the cumulative volume lost through four periodic budworm infestations amounted to 45.7 percent of the potential cumulative volume. Though growth losses were not measured for the Cougar unit during this evaluation, the potential for volume losses due to budworm defoliation is real. Moreover, the volume loss due to budworm is compounded by volume losses resulting from mistletoe infection.

During the 1986 season, a high proportion of trees (86.2 percent of the Douglas-fir trees per acre) experienced very heavy defoliation from budworm. Since the current outbreak is relatively young, we would expect continued heavy defoliation for several more years. Cumulative impact of past and present feeding is heaviest in the smaller diameter classes (4 to 8 inches DBH; Table 5). We interpret these results to mean that repeated years of heavy budworm feeding eventually leads to higher rates of defoliation among the smaller trees, in spite of the trees' recuperative abilities. This repeated severe feeding damage will have a marked impact on the radial growth of Douglas-fir (especially in the smaller size classes) during, and for some time following, the outbreak.

Douglas-fir and true fir stands, as well as individual trees, exhibit an enormous amount of variability in response to defoliation by the western spruce budworm. Studies and observations on the effects of defoliation by budworm on stands and individual trees throughout the West have confirmed this variability. Certain stands, and certain trees within a stand, seem to be more adversely affected by budworm defoliation than others. Our observations of budworm-caused defoliation and damage suggest that the Cougar Timber Sale is probably one of greater risk, both in terms of susceptibility (= the probability of budworm infestation) and vulnerability (= the expected tree damage from an outbreak). Indeed, the current outbreak intensity confirms the susceptibility of this stand, and the amount of top-kill already evident at this early stage in the infestation suggests a high level of vulnerability.

Generally speaking, warm, dry sites tend to be more susceptible to budworm infestations than cool, wet ones (Wulf and Cates, 1985). The Cougar Timber Sale falls into the former category. Several other factors are identifiable as contributing to the relative risk of stands to budworm. Among these are such things as geographical location, habitat type, proportion of host species in the stand, degree of genetic resistance of hosts, stand density, stand structure, tree vigor, and crown exposure. Several favorable components in the Cougar unit make this stand at particular risk to damage by budworm. Most of the current stand, for example, has a very high component of smaller-sized

Douglas-fir in the understory, is multi-aged and multi-layered, has relatively low vigor, and is in the proximity of other high-risk sites, as well as being already heavily infested by budworm. Superimposed on all this is a severe infection rate by Douglas-fir dwarf mistletoe. Clearly, in view of these facts, it is assured that this site will not reach full productive potential if managed as originally prescribed for this crop tree species.

The alternatives currently recommended for prevention or suppression of western spruce budworm can be grouped into two categories: silvicultural and direct control. Silvicultural alternatives generally focus on preventing or minimizing outbreaks and subsequent damage from budworm; whereas, the objective of direct control is to suppress damaging populations of the insect. Direct control employs the use of pesticides--chemical or biological. Pesticides for direct control of budworm, and silvicultural methods, should be used in an integrated approach in both prevention and suppression modes. A number of pesticides are registered by the U.S. Environmental Protection Agency for control of western spruce budworm. The chemical insecticides acephate and carbaryl are generally considered to be the most effective. A microbial insecticide (Bacillus thuringiensis) is also available for budworm control, and Forest Pest Management's experience indicates that it is a good choice, as well.

Use of silvicultural treatments to indirectly manipulate the budworm habitat offers other possibilities for dealing with budworm in western forests. Options are somewhat limited, however. Silvicultural methods to effectively prevent or suppress budworm outbreaks, while maintaining the host type, are not fully developed as yet and seem not to be effective in the Pacific Northwest Region. Even-aged regeneration methods, such as establishing fast-growing, seral Douglas-fir after a clearcut on a grand fir habitat type, provide for thrifty new stands that are less susceptible to budworm than grand fir, in some cases. Clearcuts and seed-tree or shelterwood cuts create conditions that lead to increased mortality of dispersing budworm larvae, improved habitat for larval predators, reduction of egg deposition sites, and diminished suitability of foliage for budworm feeding (Carlson et al., 1985). Retaining budworm habitat in the proximity of an on-going outbreak, however, usually results in infestation of the stand through dispersion and migration from the adjacent infested stands, regardless of the silvicultural practices employed. The only positive way of bringing about long-term prevention or control of budworm through silvicultural means, is by implementing prescriptions that reduce budworm habitat by favoring non-host species, such as ponderosa pine or western larch for the next rotation.

Management Recommendations

Our survey has revealed that the Douglas-fir component of the stand on the Cougar Timber Sale is being severely affected by Douglas-fir dwarf mistletoe and western spruce budworm. The damage caused by these pests will continue and, most likely, increase in future years if the stand is not appropriately managed to minimize or eliminate damage. For the Cougar Timber Sale, Forest Pest Management makes the following specific recommendations:

1. The shaded area on the unit map (Fig.1) has a good ponderosa pine understory. This portion of the stand can be managed as originally prescribed by overstory removal and retention of the best understory trees.

2. In the remainder of the area surveyed, we recommend that the existing understory **not** be managed under any circumstances. Rather, we recommend a regeneration harvest and reforestation with ponderosa pine. Patch clearcutting appears to us to be a more viable option than a seed tree cut because of poor condition and scattered distribution of possible seed trees. A seed tree cut with interplanting might be an option, however.

3. Sunflower Creek at the north end of the unit--a tributary of the South Fork John Day River--is a sensitive fisheries component. Any regeneration harvesting on the Cougar unit should be designed to cause as little impact on this stream as possible. Small-staged clearcuts, for example, would be prefereable to treatment of the whole block at once. If a buffer is left along the stream to protect it, the Douglas-fir component will continue to decline and may eventually have to be removed.

We believe that managing the Cougar Timber Sale by favoring ponderosa pine offers the best opportunity to: 1. decrease or eliminate the mistletoe problem; 2. decrease susceptibility and vulnerability to western spruce budworm; and 3. maximize the long-term yield potential of the stand.

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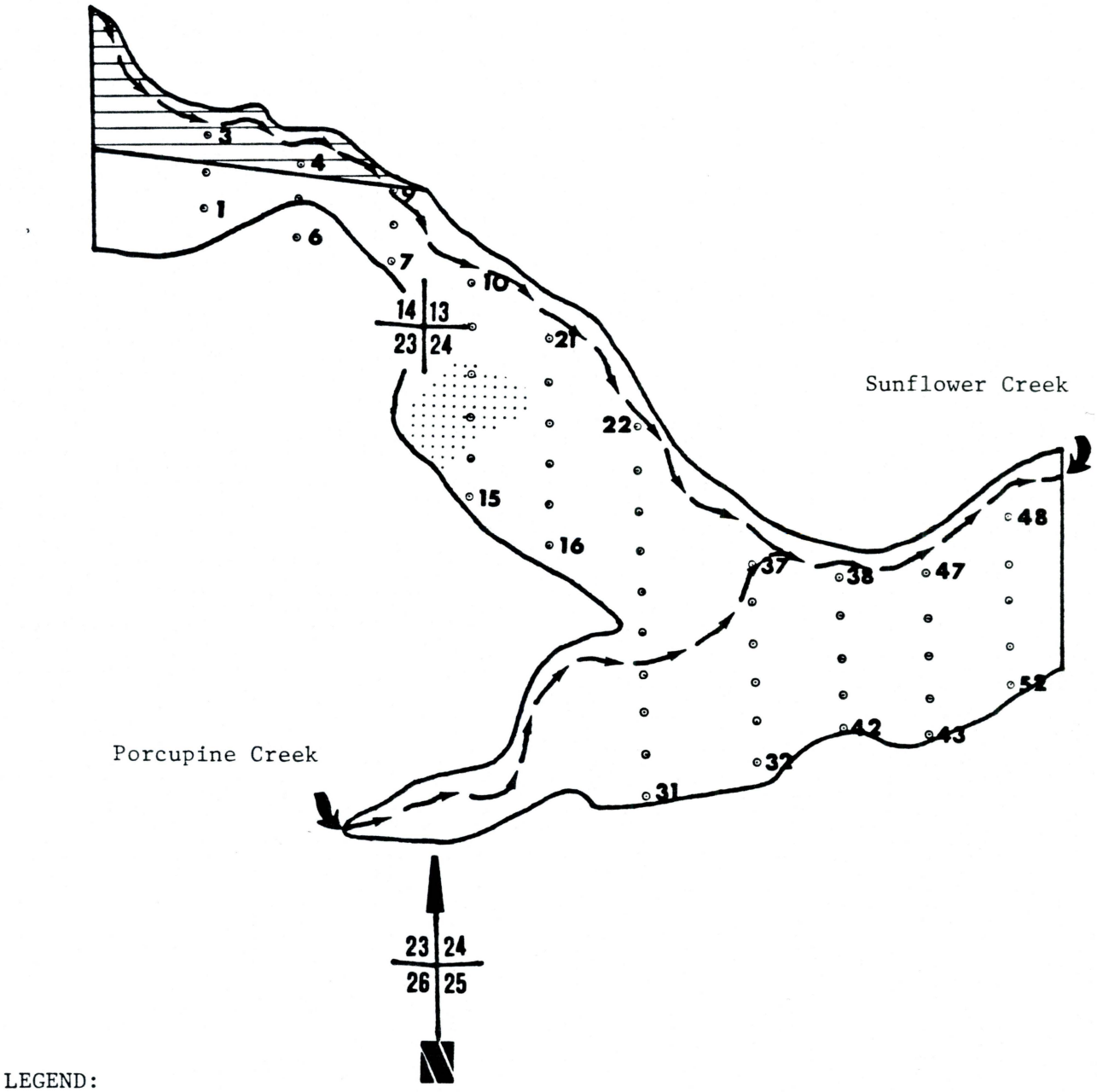
Figure 1. Surveyed Portion of Cougar Timber Sale (T. 16 S., R. 26 E.) Paulina Ranger District, Ochoco National Forest, 1986.



LEGEND:

Private Land

Plots

Area Manageable under Current Silvicultural Prescription

Figure 2. Overstory Douglas-fir trees infected by dwarf mistletoe. Note heavy, misshapen witch's brooms induced by the pathogen.

Figure 3. Douglas-fir understory on the Cougar Timber Sale severely infected by dwarf mistletoe. Understories infected to this degree are poor management risks.

Figure 4. Understory Douglas-fir on the Cougar Timber Sale completely defoliated by western spruce budworm.

Diameter Class	Douglas-fir		Ponderosa Pine		Western Juniper		Total All Species	
4	121.0	(10.6)	26.1	(2.3)	8.8	(0.8)	155.9	(13.7)
6	80.7	(15.8)	3.8	(0.8)	3.8	(0.8)	88.3	(17.4)
8	49.7	(17.0)	2.2	(0.8)	0.0	(0.0)	51.9	(17.8)
10	15.2	(8.3)	1.4	(0.8)	0.0	(0.0)	16.6	(9.1)
12	8.6	(6.8)	2.9	(2.3)	0.0	(0.0)	11.5	(9.1)
14	4.2	(4.5)	0.0	(0.0)	0.7	(0.8)	4.9	(5.3)
16	2.7	(3.8)	1.1	(1.5)	1.6	(2.1)	5.4	(7.4)
18	1.3	(2.3)	0.4	(0.8)	0.0	(0.0)	1.7	(3.1)
20	0.7	(1.5)	1.0	(2.3)	0.3	(0.8)	2.0	(4.6)
22	0.9	(2.3)	0.6	(1.5)	0.0	(0.0)	1.5	(3.8)
24	1.0	(3.0)	1.2	(3.8)	0.0	(0.0)	2.2	(6.8)
26	0.2	(0.8)	0.4	(1.5)	0.0	(0.0)	0.6	(2.3)
28	0.2	(0.8)	1.9	(8.0)	0.0	(0.0)	2.1	(8.8)
30	0.2	(0.8)	0.3	(1.5)	0.0	(0.0)	0.5	(2.3)
32	0.0	(0.0)	0.5	(3.0)	0.0	(0.0)	0.5	(3.0)
34	0.1	(0.8)	0.1	(0.8)	0.0	(0.0)	0.2	(1.6)
36	0.1	(0.8)	0.5	(3.8)	0.0	(0.0)	0.6	(4.6)
38	0.1	(0.8)	0.2	(1.5)	0.0	(0.0)	0.3	(2.3)
40	0.0	(0.0)	0.2	(1.5)	0.0	(0.0)	0.2	(1.5)
Total	286.9	(80.7)	44.8	(38.5)	15.2	(5.3)	346.9	(124.5)
Percent	82.7	(64.8)	12.9	(30.9)	4.4	(4.3)	100.0	(100.0)
DBH (QMD)	13.5		26.5		14.1		18.6	
No. Samples	53		53		53		53	
CV %	121.4	(87.2)	247.9	(111.6)	474.9	(446.4)	97.5	(62.9)
SE (Mean)	47.848	(9.667)	15.242	(5.898)	9.893	(3.239)	46.470	(10.757)
SE %	16.7	(12.0)	34.1	(15.3)	65.2	(61.3)	13.4	(8.6)

Table 1: Average number of trees and square foot basal area (in parentheses) per acre in the surveyed portion of the Cougar Timber Sale by diameter class and tree species, Ochoco National Forest, 1986.

Diameter Class	ALIVE		DEAD	
	Apparently Healthy	Mistletoe Infected	Mistletoe Infected	Mistletoe Infected and Root Diseased[1]
4	78.0 (6.8)	25.9 (2.3)	17.3 (1.3)	0.0 (0.0)
6	42.3 (8.3)	26.9 (4.8)	7.7 (1.5)	3.8 (0.7)
8	34.6 (12.0)	10.8 (3.8)	2.2 (0.8)	2.2 (0.8)
10	8.3 (4.5)	6.9 (3.8)	0.0 (0.0)	0.0 (0.0)
12	5.8 (4.5)	2.9 (2.3)	0.0 (0.0)	0.0 (0.0)
14	3.5 (3.8)	0.7 (0.8)	0.0 (0.0)	0.0 (0.0)
16	0.5 (0.8)	0.5 (0.8)	1.1 (1.5)	0.5 (0.8)
18	0.0 (0.0)	1.3 (2.3)	0.0 (0.0)	0.0 (0.0)
20	0.3 (0.8)	0.3 (0.8)	0.3 (0.8)	0.0 (0.0)
22	0.2 (0.8)	0.6 (1.5)	0.0 (0.0)	0.0 (0.0)
24	0.0 (0.0)	0.5 (1.5)	0.2 (0.8)	0.0 (0.0)
26	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)
28	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)
30	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)
32	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)
34	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
36	0.0 (0.0)	0.1 (0.8)	0.1 (0.8)	0.0 (0.0)
38	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
40	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Total	173.5 (42.3)	78.1 (28.7)	28.9 (7.5)	6.5 (2.3)
Percent	60.4 (52.3)	27.2 (35.5)	10.1 (9.3)	2.3 (2.9)

[1] Root disease involved was brown cubical root and butt rot caused by Phaeolus schweinitzii.

Table 2: Average number of Douglas-fir trees and square foot basal area (in parentheses) per acre in the surveyed portion of the Cougar Timber Sale by diameter class, tree condition, and disease category, Ochoco National Forest, 1986.

Diameter Class	Percentage of Top Killed by Budworm Feeding					Total All Categories
	Unaffected	1 to 5%	6 to 10%	11 to 20%	21% or More	
4	86.4 (7.5)	8.6 (0.8)	0.0 (0.0)	0.0 (0.0)	8.6 (0.7)	17.2 (1.5)
6	57.7 (11.3)	11.6 (2.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	11.6 (2.3)
8	32.4 (11.3)	8.6 (2.9)	2.2 (0.6)	2.2 (0.8)	0.0 (0.0)	13.0 (4.3)
10	11.1 (6.0)	2.8 (1.5)	1.4 (0.8)	0.0 (0.0)	0.0 (0.0)	4.2 (2.3)
12	8.6 (6.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
14	3.5 (3.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.7 (0.8)	0.7 (0.8)
16	1.1 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
18	0.9 (1.5)	0.0 (0.0)	0.4 (0.8)	0.0 (0.0)	0.0 (0.0)	0.4 (0.8)
20	0.0 (0.0)	0.3 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.8)
22	0.6 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.8)	0.3 (0.8)
24	0.5 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
26	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
28	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
30	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
32	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
34	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
36	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
38	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
40	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Total	203.4 (55.1)	31.9 (8.3)	4.2 (3.8)	2.2 (0.8)	9.6 (2.3)	47.9 (15.2)
Percent	80.9 (78.4)	12.7 (11.8)	1.7 (5.4)	0.9 (1.1)	3.8 (3.3)	19.1 (21.6)

Table 3: Average number of live Douglas-fir trees and square foot basal area (in parentheses) per acre in the surveyed portion of the Cougar Timber Sale by diameter class and budworm-caused dead top category, Ochoco National Forest, 1986.

Diameter Class	Percentage of Top Bared by Budworm Feeding					Total All Categories
	Unaffected	1 to 5%	6 to 10%	11 to 20%	21% or More	
4	26.0 (2.0)	0.0 (0.0)	25.9 (2.3)	17.3 (1.5)	34.5 (3.0)	77.7 (6.8)
6	7.7 (1.6)	7.7 (1.5)	27.1 (5.0)	19.3 (3.8)	7.7 (1.5)	61.8 (11.8)
8	2.2 (0.8)	4.3 (1.5)	10.8 (3.8)	15.1 (5.3)	13.0 (4.4)	43.2 (15.0)
10	0.0 (0.0)	4.2 (2.3)	5.5 (3.0)	2.8 (1.5)	2.8 (1.5)	15.3 (8.3)
12	0.0 (0.0)	3.8 (2.9)	1.9 (1.5)	1.9 (1.5)	1.0 (0.8)	8.6 (6.7)
14	1.4 (1.5)	0.0 (0.0)	0.0 (0.0)	1.4 (1.5)	1.4 (1.5)	2.8 (3.0)
16	0.0 (0.0)	0.0 (0.0)	0.5 (0.8)	0.0 (0.0)	0.5 (0.8)	1.0 (1.6)
18	0.0 (0.0)	0.0 (0.0)	0.4 (0.8)	0.4 (0.8)	0.4 (0.8)	1.2 (2.4)
20	0.0 (0.0)	0.3 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.8)
22	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.6 (1.5)	0.3 (0.8)	0.9 (2.3)
24	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)
26	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
28	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
30	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)
32	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
34	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
36	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
38	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
40	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Total	37.7 (7.5)	20.5 (9.8)	72.5 (19.6)	58.8 (17.4)	61.6 (15.1)	213.4 (61.9)
Percent	15.0 (10.8)	8.2 (14.1)	28.9 (28.2)	23.4 (25.1)	24.5 (21.8)	85.0 (89.2)

Table 4: Average number of live Douglas-fir trees and square foot basal area (in parentheses) per acre in the surveyed portion on the Cougar Timber Sale by diameter class and budworm-caused bare top category, Ochoco National Forest, 1986.

Diameter Class	Budworm Defoliation Classes—All Years of the Outbreak					Current Year's (1986) Budworm Defoliation Classes				
	Very Light	Light	Moderate	Heavy	Very Heavy	Very Light	Light	Moderate	Heavy	Very Heavy
4	25.9 (2.0)	8.6 (0.8)	26.0 (2.3)	8.6 (0.8)	34.6 (3.0)	8.7 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	94.9 (8.3)
6	11.6 (2.3)	15.5 (2.8)	11.5 (2.3)	19.2 (3.8)	11.5 (2.3)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	11.6 (2.3)	57.7 (11.3)
8	4.4 (1.6)	6.5 (2.3)	4.3 (1.5)	19.4 (6.7)	10.8 (3.7)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	8.6 (2.8)	36.8 (12.8)
10	2.8 (1.6)	0.0 (0.0)	6.9 (3.6)	4.2 (2.3)	1.4 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.4 (0.8)	13.8 (7.5)
12	3.8 (2.6)	1.9 (1.5)	1.0 (0.8)	1.9 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.9 (0.7)	1.0 (0.8)	6.7 (5.3)
14	1.4 (1.6)	0.0 (0.0)	1.4 (1.5)	1.4 (1.5)	0.0 (0.0)	1.4 (1.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2.8 (3.0)
16	0.0 (0.0)	0.5 (0.8)	0.5 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.1 (1.5)
18	0.4 (0.8)	0.0 (0.0)	0.9 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.8)	0.9 (1.5)
20	0.3 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
22	0.3 (0.8)	0.0 (0.0)	0.6 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.8)	0.0 (0.0)	0.6 (1.5)
24	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.5 (1.5)
26	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)
28	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)
30	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.8)
32	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
34	0.0 (0.0)	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
36	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
38	0.1 (0.8)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.8)
40	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
TOTAL	51.2 (15.7)	33.3 (9.8)	53.1 (15.8)	55.1 (18.2)	58.3 (9.8)	10.4 (3.0)	0.0 (0.0)	1.2 (1.5)	23.0 (7.5)	216.6 (58.2)
PERCENT	20.4 (12.6)	13.3 (14.1)	21.2 (22.8)	21.9 (26.3)	23.2 (14.1)	4.1 (4.3)	0.0 (0.0)	0.5 (2.1)	9.2 (10.7)	86.2 (82.9)

Table 5: Average number of live Douglas-fir trees and square foot basal area (in parentheses) per acre in the surveyed portion of the Cougar Timber Sale by diameter class and budworm defoliation class (total missing foliage and current defoliation), Ochoco National Forest, 1986.

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